

PM_{2.5} Sulfate and Organic Carbon Estimates for 2010

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Summary

An air quality assessment by the Southern Appalachian Mountains Initiative (SAMI) has at its center a suite of atmospheric model simulations using the URM-1ATM model. Modeling consists of nine meteorological episodes encompassing 69 days. All episodes occurred during 1991-1995. The modeling domain was designed to maximize the quality of information produced along the spine of the southern Appalachian Mountains from Alabama northeastward through the Virginias. Results should provide insight into expected trends across the eastern U.S. in various pollutant species over the next few years. Significant changes in fine particles (PM_{2.5}) are anticipated in response to expected emission changes between the 1991-1995 simulation periods and 2010. Modeled changes in PM_{2.5} sulfate and organic carbon (OC) are described here.

SAMI Modeling – The URM-1ATM model simulates atmospheric processes relevant to the formation of ozone, fine particles and acid deposition. SAMI simulations included a winter, four spring and four summer episodes. Daily average concentrations of total measured PM_{2.5} mass were used to sort days into five classes. Data for this purpose were taken from monitoring stations at two national parks: Great Smoky Mountains (TN) and Shenandoah (VA). Thus, one set of episode classifications was prepared for each park. The two classes with the highest PM_{2.5} concentrations represent the 20 percent highest of all days in the data base for each national park.

A base case simulation was made for each episode for which realistic emissions input data were prepared. Actual hourly emissions were used, when available, for the large point sources operated by electric utilities in the SAMI region. SAMI modeled 2010 emissions based on a variety of assumptions about growth in population; growth in power demand; economic expansion; turnover in industrial facilities, utility plants and motor vehicles; and future air quality regulations. Results presented here are for the so-called 2010 “On-the-way” emissions scenario developed and modeled by SAMI (now referred to as strategy “A2”).

The A2 scenario is essentially the best guess regarding future emissions in the absence of new regulatory intervention. A2 assumes that existing or pending regulatory controls will be in place by 2010. All utility controls required by Title IV, any state implementation plans and the EPA regional NO_x reductions were explicitly modeled. All announced regulations affecting motor vehicles were included. Population growth was assumed to affect both area and mobile source emissions.

The most problematic issue was the effect of future power demand and electric utility deregulation on the operation of utility fossil fuel boilers. Actual utility emissions were used for the base cases to the extent that data were available. Otherwise, average emissions were modeled (these are influenced by an assumption about the typical availability of plants and the seasonal demand for electricity). For 2010, utility emissions were limited by expected controls, but increased demand for electricity and utility deregulation were assumed to increase the fraction of the time that the plants will be operating. Thus, emissions actually increased between the base case and 2010 A2 simulations for some plants on some episode days.

Under the A2 scenario, SO₂ is forecast to drop by 23% from 1990 to 4.6 × 10⁶ tons yr⁻¹ by 2010. Likewise, NO_x is forecast to drop by 23% to 3.3 × 10⁶ tons yr⁻¹ by 2010. Nearly all the SO₂ decline is from the utility sector, while both utilities and motor vehicles contribute to the NO_x decline. Changes in emissions of organic gases (VOCs), which include precursors to organic carbon aerosols, are forecast to change little between 1990 (3.7 × 10⁶ tons yr⁻¹) and 2010 (3.3 × 10⁶ tons yr⁻¹). Primary PM_{2.5} emissions (all species) are estimated to remain nearly constant at just over 1.2 × 10⁶ tons yr⁻¹. The most problematic of the relevant gas species is ammonia (NH₃) which forms ammonium sulfate and, when conditions are favorable, ammonium nitrate. NH₃ is forecast to increase about 60% to almost 0.8 × 10⁶ tons yr⁻¹, and most of this occurs in the agricultural sector. However, the accuracy of NH₃ emissions is not known.

The SAMI modeling focus was providing guidance on air quality changes expected in southern Appalachian Class 1 areas. However, results also provide information on expected aerosol changes elsewhere. Modeling generally indicates that the largest decreases in aerosol levels between the base cases and 2010 will occur in those places and on those days experiencing the highest concentrations of particles.

In Class 1 areas of primary interest—Great Smoky Mountains (GSM) and Shenandoah (SHE)—the forecast sulfate changes were slightly negative on an annual average basis. Annual decreases of 5% are projected for the GSM, while at SHE slightly larger drops of about 13% are anticipated. For OC, the second largest $PM_{2.5}$ component, no significant change in concentration is anticipated. In 2010, fine sulfate is expected to average $4.0\text{--}4.5\ \mu\text{g m}^{-3}$, while OC is anticipated to average $2\text{--}3\ \mu\text{g m}^{-3}$. Changes on individual days, especially for acute cases, are forecast to show greater improvement. For example, modeled days representing periods having the highest 20% of $PM_{2.5}$ concentrations averaged sulfate decreases of almost $2\ \mu\text{g m}^{-3}$ at GSM and about $2.5\ \mu\text{g m}^{-3}$ at SHE. On these same days, average predicted changes in OC are negligible.

The story for $PM_{2.5}$ is more encouraging when viewed across the region. Modeled sulfate changes on individual summer days are as large as $-17\ \mu\text{g m}^{-3}$ in some places. Summer episode-averaged daily maximum decreases in the SAMI region ranged between $-4\ \mu\text{g m}^{-3}$ and $-10\ \mu\text{g m}^{-3}$. Spring and winter sulfate reductions are modeled to be much smaller, with episode-averaged daily maximum decreases falling between 0 and $-3.5\ \mu\text{g m}^{-3}$. Thus, fine particle sulfate levels are predicted to drop most in summer, when concentrations are highest, and less in winter and spring (and by extrapolation, autumn).

Predicted changes in OC levels are much different from those of sulfate. First, for many episodes modeling suggests widespread, small declines in OC by 2010. These decreases are predominantly in rural areas and are generally smaller than $0.5\ \mu\text{g m}^{-3}$ in magnitude. However, the modeling also indicates that urban OC is expected to increase. For most episode days the magnitude of the urban increases in OC are larger than the largest decreases in rural OC. Summer is predicted to show the largest urban increases in OC. The largest predicted increase in daily maximum OC within the SAMI region was almost $4\ \mu\text{g m}^{-3}$ during a June episode. However, even during winter and spring the increases in daily average urban OC are usually larger than any modeled decreases outside the urban areas. Thus, the expected decline in VOC emissions must be occurring predominantly in non-urban areas. Urban growth, especially in cities like Atlanta and Birmingham, is expected to drive OC levels upward.

Conclusions – Modeled decreases in fine sulfate are larger in magnitude than increases in fine OC. Therefore, $PM_{2.5}$ mass decreases are expected in the SAMI region. These decreases are expected to be larger in rural areas than in and near cities because of influences from increasing urban VOC and primary OC emissions. Changes in non-urban $PM_{2.5}$ levels are expected to produce small benefits to visibility in Class 1 areas, but the magnitude of the benefits is not expected to be large enough to meet regional haze goals. Rural areas that are already in attainment of the annual $PM_{2.5}$ standard are likely to remain that way through 2010. However, larger urban areas where the annual standard of $15\ \mu\text{g m}^{-3}$ is being exceeded are not likely to experience much benefit from the decline in sulfate because of offsets from OC increases.